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EVOLUTION OF THE COAL RESERVE CONCEPT IN CANADA

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EVOLUTION OF THE COAL RESERVE CONCEPT IN CANADA

by

H.G. Naidu*

ABSTRACT

The methods of estimating coal resources/reserves have gradually developed from mere guessing to a systematic approach. To be considered as reserves, coal must satisfy certain criteria related to geology, mining technology, market, socio-economic factors and government involvement. On technical grounds resources have been classified into three catagories: measured, indicated and inferred, and into two sub catagories: "of immediate interest" and "of future interest". The quality of coal has also become an increasingly significant criterion of coal reserves. Thus from its original image the coal reserve concept in Canada as applied by CANMET has assumed a dynamic status where the amount of reserves is variable. This report focuses upon the various factors and criteria that distinguish reserves from resources.

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ÉVOLUTION DU CONCEPT DE LA RÉSERVE DE CHARBON AU CANADA

par

H.G. Naidu*

RÉSUMÉ

Les méthodes permettant d'évaluer les ressources et réserves de charbon ont évolué graduellement de la simple hypothèse à l'approche systématique. Pour être classé en tant que réserve, le charbon doit remplir certains critères ayant trait à la géologie, la technologie minière, les facteurs socio-économiques et la participation du gouvernement. D'après des exigences techniques, les ressources ont été classées en trois catégories: ressources mesurées, connues, et supposées, et en deux sous-catégories: ressources d'intérêt immédiat, d'intérêt pour l'avenir. La qualité du charbon des réserves est également devenue un critère de plus en plus important. Par conséquent, à partir de son image initiale, le concept des réserves de charbon au Canada tel qu'appliqué par le CANMET à acquis un statut dynamique où le nombre de réserves varie. Dans ce rapport l'auteur s'arrête sur les différents facteurs et critères qui permettent de distinguer les réserves des ressources.

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INTRODUCTION

Coal has been mined in Canada for over 250 years, but until the early part of this century no attempt was made for a nation-wide assessment of the quantity in the ground. From 1913 to the late 1960's attempts were made to estimate only the quantity of coal in the ground with qualifications based on the levels of confidence generated through exploration. In 1973, a sudden surge in oil prices created an urgency to evaluate the coal resource more realistically in order to assess the potential contribution of this energy source to reducing Canada's dependency on imported oil. In order to carry out this work, the Federal Department of Energy, Mines and Resources asked CANMET to establish a Coal Reserve Assessment Group. It was modelled on the previously established Uranium Resources Appraisal Group which produced annual assessments of Canada's uranium supply and demand.

The main task of CANMET's Coal Reserve Assessment Group is to assess and report on the quantity and quality of Canada's coal that can be mined economically with current technology, and under prevailing market conditions. This paper describes the development of assessment methods and factors influencing the reserves estimates.

Nomenclature is a very important aspect of non-renewable resource assessment. The terminology used by CANMET's Coal Reserve Assessment Group is included in Appendices-A and B.

HISTORICAL BACKGROUND OF COAL RESERVES ASSESSMENT

The first assessment of coal in Canada was done by Dowling in 1913 (1) and dealt essentially with resources although both "actual reserves" (1/3 of total) and "probable reserves" (2/3 of total) were determined.
Nearly three decades later in 1947, MacKay (2) Published a Comprehensive reappraisal of the first estimate of Canada's coal resources

using more realistic limiting values for such factors as seam thickness and depth of cover. This reduced the original assessment by a factor of ten. Later in 1960, MacKay revised the 1947 figures based on new information which resulted in an estimate of 60 billion tons of probable and 33 billion tons of possible resources. In 1973, the Department of Energy, Mines and Resources reported 9.8 billion tons of measured, 50.2 billion tons of indicated and 58.6 billion tons of inferred resources (3) (Terms defined in Appendix A). These figures were based on a study on the Western Canadian coal resources by Latour and Christmas (4).

Not until 1976 was any attempt made to provide a meaningful definition of reserves. Originally, resources assessment concentrated on the quantity of coal in place, irrespective of quality. In 1976, the Department of Energy, Mines and Resources undertook to develop programs for gathering data on coal supply and demand along with pertinent data on quantity, quality and mineability as well as economic information (4,5). During this period a realistic definition was given to reserves as that part of measured and indicated resources of immediate interest which can be mined (Fig. 1)(9):

- with current technology,
- in the present economic conditions,
- for which the infrastructure is in place,
- which is legally open to mining, and
- for which a market has been established,

In 1979 CANMET and the Geological Survey of Canada (GSC) agreed to share the workload with CANMET concentrating on reserves while GSC studies resources.

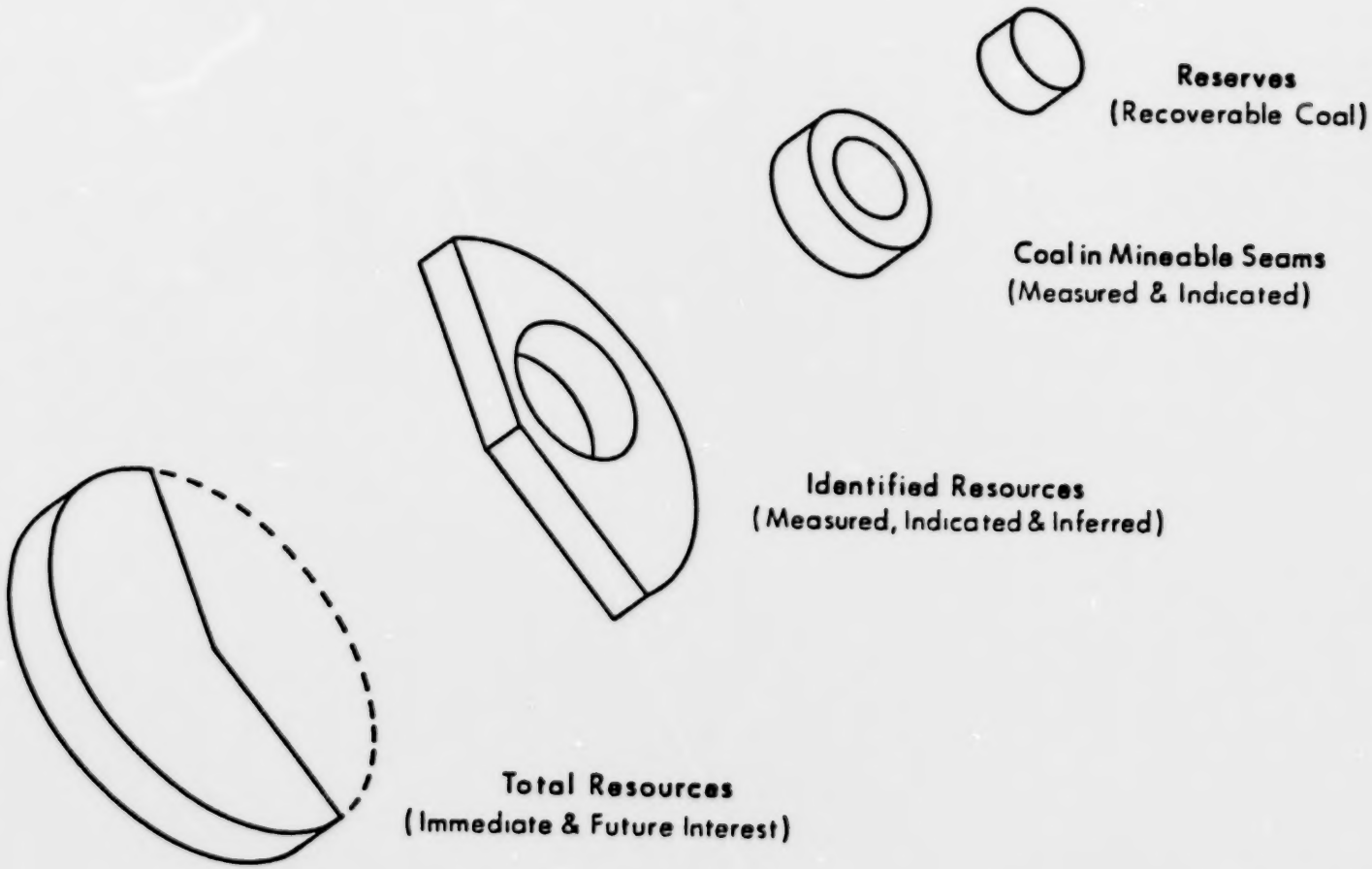

Figure 1. Delineation of Canadian Coal Resources and Reserves. (9)

The above figure has been taken from publication of U.S. Department of Energy "Demonstrated reserve base of Coal in the United States on January, 1980". The title of the figure "Delineation of U.S. Coal Resources and Reserves" and the details have been modified to suit Canadian conditions.

FACTORS INFLUENCING COAL RESERVES

Coal reserves, a variable quantity is influenced by many factors. These factors can be divided in different groups namely natural factors, mining technology, market, socio-economic and government involvement.

The natural factors include seam thickness, seam frequency, depth of cover, seam inclination, conditions of roof and floor, coal quality, ground water, tectonics, stratigraphy, remoteness etc. These factors have been analyzed individually in the following paragraphs.

Seam Thickness

From the resources point of view, the thicker the seam, the greater the resources per unit of seam area. But when one considers reserves the thicker seam is not always bigger or better. For seams which can be mined by surface methods, reserves are generally a direct function of seam thickness. In case of seams mineable only by underground methods, there is an optimum seam thickness for maximum reserve recovery with the present state of mining technology. In fact, very thick seams pose problems that can reduce percentage recovery which reduce the amount of reserves. A value of 2-4 m of seam thickness may be quoted as optimum for underground mining. In the mountain region, there are several coalfields where large seam thickness mineable by underground methods only, have low percentage of coal recoveries.

Seam Frequency

Although large amounts of coal may exist in a sequence of seams that could be mined by underground methods, the recovery may go down drastically because of selective seam mining which sterilizes the other seams. This factor is particularly significant in closely spaced or contiguous seams. The overlying seams can be partially sterilized for a considerable distance (upto hundreds of metres) above an extracted seam due to fractures developing in the intervening strata and the overlying seams.

Depth of Cover

For a shallow depth (less than 50 m) a coal seam may be extracted almost 100% by surface mining. Beyond this depth when underground mining is a must, recovery is likely to drop because of ground control problems associated with loose or soft cover (Fig. 2). This is more pronounced in thick seams. When the depth exceeds about 500 m, ground control problems play a much greater role in reducing recovery. For underground mining the recovery factor between the two extremes of depth is relatively higher.

Seam Inclination

Recovery is also affected by inclination of coal beds. Very steep seams are difficult to mine and it is more difficult to transport supplies and equipment. Also, in underground mining, the problem of load transfer in steep seams creates ground control problems, which reduces the reserves factor. This is generally true if the sequence of mining is from the rise side to the dip side, which is a common practice for economical reasons.

Roof and Floor Condition

Problems of roof and floor in underground coal mining and the floor in surface coal mining can reduce the mining potential of a particular seam Some modification, for example, leaving coal in the roof or in the floor may reduce recovery percentage but keep the seam in the reserve category.

In case of thin seams, if coal is left in the roof or floor, the remaining thickness of coal may not be mineable with the current technology. If additional dirt is to be mined along with the seam, it becomes costlier in mining as well as washing. Such conditions exist in the Lethbridge Coalfield, Alberta.

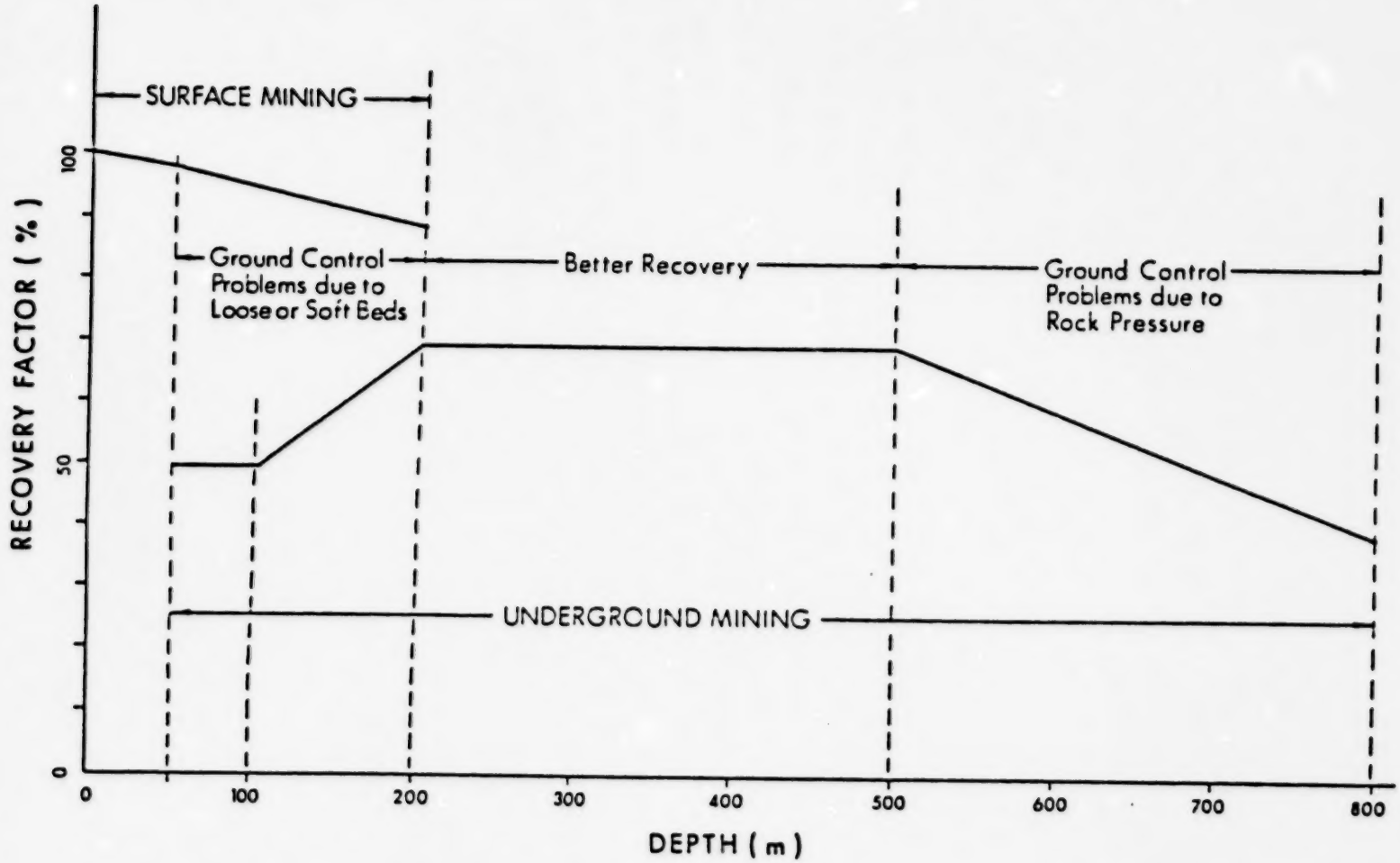

Fig. 2 - Effect of depth on reserve

Coal Quality

The demand and price for coal vary with its quality, e.g. cok coal, bituminous thermal coal, sub-bituminous thermal coal and lignite of low thermal value etc. Because of the quality, a particular seam may be deleted from the reserves category.

Coal quality includes: proximate analysis, ultimate analysis, petrological analysis, and ash analysis. The reserves factor will be a function of all these quality characteristics and may change with time because of the changing demand for a particular quality of coal. Coal quality also includes gassiness, liability to spontaneous combustion, dust forming tendency, strength and other criteria of coal. These criteria are very important in deciding the methods of mining, which in turn control production, productivity, cost, safety and recovery.

Ground Water

Ground water affects coal recovery in three major ways: cost of removing the water, unfavourable working environment and ground control problems. Presence of water may make a potentially workable coal seam completely unworkable hence affecting the catagory of the reserves.

Tectonics

In the presence of a fault, one can expect ground control problems, gas emissions and water percolation. Gas emission as well as spontaneous heating characteristics are also affected by the nature and the frequency of the joints system. Folding processes can make the seam thicker or thinner locally causing difficulty to mining. Faults can also render some areas barren where coal was expected. Joint planes also drastically affect the stability of slopes in open pit mining.

Stratigraphy

The superincumbent strata as well as strata below the seam have great influence on the mineability of a seam especially for underground mining. A good roof is one which poses least problems during mining but caves without undue delay, once coal extraction is completed and supports removed. Thus, either very strong or very weak roofs, result in additional costs and safety hazards which reduces the reserves.

In the case of surface mining, the adjacent strata, affects the stability of slopes - with stronger rocks, steeper slopes can be maintained. This results in better overburden to coal ratios. However if the strata is too strong, it may require additional equipment, manpower and cost for removal.

Remoteness

Many coalfields in Canada are located in remote areas. To transform this resources into reserves, the constraints are:

- long distance transport
- high cost of materials and energy, and
- cost and problems of developing infrastructure

Even though billions of tonnes of coal resources exist in these areas, the actual recoverable reserves is substantially reduced.

The resources in a coalfield is fixed, except through addition by new discoveries or reduction by mining, but recoverable reserve is a variable. A property in such an area may not be economically viable but sometimes with the incentives from governments through subsidy, grants, etc., it could become viable at some future date.

MINING TECHNOLOGY

Mining technology plays a major role in transforming resources to reserves. In the past, coal was essentially mined by conventional underground methods. Recovery was often very low especially in thick and steep seams. With the development of heavy earth moving machineries, surface

mining became possible to greater depths. In Canada, surface coal mining has reached a depth of about 200 m.

Underground coal mining technology also has witnessed significant advancement, e.g. continuous room and pillar mining, mechanized longwall mining with shield support, improved recovery, etc. Some other techniques, for example, hydraulic mining, punch mining, auger mining, borehole hydraulic mining etc. may improve recovery by rendering some seams or areas mineable which otherwise would be completely lost. Hydraulic mining has been proven to be a practical method of extracting thick and steep seams (35°). With this method much higher recovery (55%) and productivity of over 21 tons per manshift has been achieved (7). However, additional precautions are required in hydraulic mining to prevent spontaneous combustion of coal resulting in mine fire. The one and only operating hydraulic mine in Canada (Westar Mining in South East B.C.) closed down last year due to a mine fire. Productivity has increased with the use of draglines with booms of 120 m in length and with bucket capacitites of 70 cu.m. In the plains of Alberta and Saskatchewan, productivity of over 100 tonnes per manshift has been achieved, making it possible to keep the industry alive against stiff competition from other cheap sources of energy in the region.

Recently, Obed Mountain Mine introduced a continuous surface mining equipment known as EASI MINER with a productive capacity of 2000T-3000T per hour. Studies are underway to review the use of bucketwheel in surface coal mines.

Market

Market conditions can dictate selective mining for a particular seam that renders portions of that or adjacent seams lost for good. At a later date market may change but the earlier selective mining has sterilized what would otherwise now become a reserve. This has been the case at different times in many coalfields in the world. This is especially noticeable in coalfields having a high density of seam frequency. Often a particular working seam loses its market and mining is suspended for a length of time. In some cases a part of this seam becomes unworkable because of degradation in conditions, such as flooding, more complicated ground control problems, etc. On the other hand, due to lack of market a coalfield may lose its infra-

structures if mining is suspended for a considerable time. This is very much the case for many of the underground mines of Alberta in the plains and foothills with sub-bituminous coal reserves. According to the present market situation, there is little indication of any of these opening up in the near future.

Transportation and Competition

Most of the coal deposits of western Canada occur at about 3200 km from the main domestic markets in the east and also about 1000 km from the nearest sea coast at the Pacific Ocean for export market. This makes the cost of transport from the mine to the port some $20-$25 per tonne of coal. This is an obstacle which needs to be offset by efficient mining. On the favourable side, the Canadian coals are of good quality and has low sulphur content. Another constraint is the relatively high wages in Canada which make the industry less competive in the export market compared to Australia and South Africa.

GOVERNMENT INVOLVEMENT (PROVINCIAL AND FEDERAL)

Government plays some important roles in transforming resource into reserves. To bring any mining property into the production stage, a potential operator has to get the application processed through Government approval procedures and must guarantee they will adhere to specific environmental standards. Government does play a positive role in the development of coal industry by providing incentives through grants, subsidies, free infrastructure and help in export trade. This is likely to affect transformation of resources to reserves.

Approval Procedures

This involves many procedures in the form of submissions, public disclosures, studies etc. which are costly and time consuming. Due to this reason many potential mine operators stop exploring the possibility of opening up a mine on economic grounds and time limitations. Recently British Columbia has modified some of these approval procedures to expedite the process.

Environmental Standards

Government's requirements on air, water, wildlife, forestry, parks and land classification have resulted in the sterilization of many potential mineable coalfields. Modification of current standards could modify coal reserves.

Incentives

Government has and can play a big role in trasforming resources into reserves by providing grants, subsidies or cost-free infrastructure. The most recent example is the development of the North East B.C. Coalfield. Both provincial and federal governments provided assistance in the development of the rail routes and port facilities, without which it would be extremely difficult for the mines to open up for production. A similar example is the Smoky River mine, Grande Cache, Alberta which was given royalty relief. Governments also provide grants to the operators based on the number of jobs created, which helps the project economics to a great extent in bringing it to the production phase.

Export Trade

Governments at both the provincial and federal levels have been very supportive to industry in exporting coal, in contrast to the interventionist activities that are common in some other coal exporting countries (8). This has resulted in one of the lowest per tonne/km rail transport cost and highly efficient port facilities in Canada.(8) These factors have helped in bringing many remotely located properties into operation, thus transforming resources into reserves.

RESOURCE - RESERVE DYNAMICS

In 1970's demand for coal grew considerably which in turn increased the price of coal. It was an ideal climate in Canada for the coal industry which grew four fold. Due to less competition on in the world market, Canada was able to obtain a fairly good share of the export market. This resulted in the opening of many new coal mines thereby increasing the quantity of Canada's coal reserves. Since the begining of 1980's the coal market has

become soft which is affecting the growth of the coal industry. This will have an adverse effect on the coal reserves specially in areas where mines have to be closed down. Many factors as mentioned earlier in this report would play their role in reducing the reserves.

CONCLUSIONS

Reserves are not static numbers but are variables depending on many factors. The interactions between the various factors influence the rate and direction of converting resources to reserves and vice versa. Though Canada has some inherent drawbacks (remote locations, long distance to markets) but on the other hand the coal quality is a positive factor which helps in a big way in transforming resources into reserves.

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APPENDIX A - EMR'S COAL RESOURCE CLASSIFICATON
(essentially from Report *ER 79-9)

A meaningful reporting of Canada's coal resources must be made in the context of a classification scheme that takes into account the great diversity of the nation's coal deposits. The coal resource classification scheme classifies the resources according to two basic considerations: (a) the assurance of their existence and (b) the feasibility of exploitation. Each of these considerations is subdivided into categories having defined parameters. The definitions of terms and parameters used in this scheme are given below. They are somewhat similar to those used in the United States (Averitt, 1969) but are modified to suit local conditions that are present in Canadian coal deposits.

Definition of Resource Terms

COAL RESOURCES

The term "coal resources" is defined as the coal that is contained in seams occurring within specified limits of thickness and depth from surface.

ASSURANCE OF EXISTENCE

The terms "measured", "indicated", "inferred" and "speculative" denote the level of confidence with which given quantities of resources have been determined or estimated; they are defined as follows:

Measured Resources are resources for which tonnages are computed from information revealed in outcrops, trenches, mine workings and boreholes. The spacing of points of observation necessary to justify confidence in the character and continuity of coal seams differs from region to region according to the character of the deposits and the geological conditions. In general the points of observation should be separated by less than the following distances:

Coal regions in Canada	Maximum distance between points of observation (in metres)
Cordillera*	300
(150 m in severely contorted areas)	
Plains	
Alberta	800
Saskatchewan	800
New Brunswick	400
Nova Scotia	
Sydney Coalfield, offshore	
Harbour and Phalen seams	1 600
Other seams	800
Sydney Coalfield, onshore	800
Other coalfields	300

*Cordillera region includes all British Columbia and the Foothills and Mountain regions of Alberta.

Indicated Resources are resources for which tonnages are computed partly from specific measurements and partly from reasonable geological projections. For the general coal regions in Canada, the points of observation should be separated by less than the following distances:

*see reference 6 of the maintext

Coal regions in Canada	Maximum distance between points of observation (in metres)
Cordillera	600
(300 m in severely contorted areas)	
Plains	
Alberta	1 600
Saskatchewan	1 600
New Brunswick	800
Nova Scotia	
Sydney Coalfield, offshore	
Harbour and Phalen seams ..	4 800
Other seams	1 600
Sydney Coalfield, onshore ...	1 600
Other coalfields	600

Inferred Resources are resources for which quantity estimates are based largely on a broad knowledge of the geologic character of the bed or region and for which few measurements of seam thickness are available. The estimates are based primarily on an assumed continuity of coal seams in areas remote from the points of observation used to calculate measured or indicated resources.

Speculative Resources are resources for which quantity estimates are based on information from a few scattered occurrences. Resources of this description are mainly in frontier areas where coal mining or exploration have not taken place.

FUTURE CONSIDERATION

It is realized that it would be more meaningful to express the assurance of existence (level of confidence) by a range of possible error rather than by an arbitrary spacing of the points of observation. As an example, a measured resource estimate might be stated to have a level of confidence to within plus or minus 10 percent. To achieve this requires complex analysis.

FEASIBILITY OF EXPLOITATION

Resources of Immediate Interest consist of coal seams that, because of favourable combinations of thickness, quality, depth and location, are considered to be of immediate interest for exploration or exploitation activities. The conditions set out below do not apply rigorously in each case, but they give a general indication of thickness and depth of coal seams included in this category. In all cases, coal beds are included that are thinner or deeper than listed below but are nonetheless being mined at this time.

Cordillera:	Coal of all ranks in beds at least 1.5 m thick that can be surface-mined. Anthracitic and bituminous coal seams at least 1.5 m thick to a depth of 300 m, that are too deep for surface mining but might be mined underground.
Plains: (Alberta and Saskatchewan)	Bituminous and subbituminous coal beds at least 1.5 m thick to a depth of 230 m. Lignite seams at least 1.5 m thick that can be surface-mined (generally to depths less than 45 m).
New Brunswick:	Seams at least 0.4 m to a depth of 24 m.
Nova Scotia:	
Offshore:	Seams at least one metre thick to a depth of 1 200 m.

Nova Scotia:
Onshore: Seams at least 0.5 m thick to depths of 45 m and all seams at least one metre thick to depth of 1 200 m.

Resources of Future Interest consist of coal seams that, because of less favourable combinations of thickness, quality, depth and location, are not of immediate interest but may become of interest in the foreseeable future. The following limits are applied (excluding the resources of immediate interest described above):

Cordillera: Seams at least 1.5 m thick to depths of 750 m.

Plains: (Alberta and Saskatchewan) Seams at least one metre thick to depths of 450 m.

Nova Scotia:
Offshore: Seams at least one metre thick with depths in excess of 1 200 m.

Onshore: Seams at least one metre thick with depths in excess of 1 200 m.

FUTURE CONSIDERATIONS

When new mining technologies and/or changing economic conditions have indicated the possibility of mining thinner or deeper seams, or seams that are otherwise currently excluded from the estimates, it may become necessary to change the parameters for determining the feasibility of exploitation so as to include these coals in the estimates.

APPENDIX B

EMR'S COAL RESERVE CLASSIFICATION
(essentially from Report ER 79-9)

The terminology used in this report is similar to that given in Report ER 79-9, excepting that "mineable coal" has been replaced by the term COAL IN MINEABLE SEAMS.

COAL IN MINEABLE SEAMS is that part of measured and indicated resources of immediate interest that can be considered for mining using current technology and economics, before there is any allowance for mining losses. To qualify as COAL IN MINEABLE SEAMS the following conditions must apply:

- that feasibility studies have been done, specific plans for mining method and processing (if needed) have been adopted and the overall economic feasibility for developing the coal deposit appears favourable.
- that the necessary infrastructure (townsite, power and transportation facilities) is either in place or can be amortized through coal sales.
- that the coal is legally accessible for excavation i.e. the development considered is beyond the prospectus or initial disclosure stage in the regulatory process and has received approval-in-principle from the provincial government concerned with controlling development.
- that all coal being considered for development is likely to be marketable at minimum acceptable profit levels.

RECOVERABLE COAL is that part of COAL IN MINEABLE SEAMS that would be recoverable as run-of-mine or raw coal, making allowances for mining losses. For example, in surface mining, a portion of the top of a seam will likely be lost with overburden in the stripping operation, or a part of the seam next to the spoil pile will not likely be excavated. In underground operations the most common mining loss is associated with pillars left as supports or barriers.

CLEAN COAL is that part of RECOVERABLE COAL that remains as the prime saleable product after upgrading in a preparation plant.

SALEABLE COAL is coal that meets saleable specifications; it may be clean coal with acceptable moisture content or raw coal that is ready to be used without further upgrading. Saleable coal differs from CLEAN COAL in that its quantity includes losses in shipment and, in most instances, moisture added in processing.

*See reference 6 in the main text